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The Effect Of Releasing Stress In Tunnels On The Axial Force Of Rock Bolts In The Slopes

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***Abstract*— This paper presents numerical analysis the effect of releasing stress in tunnels on the axial force of rock bolts in the slopes by means of elasto-plastic finite element method. In numerical analysis, a 2D finite element program with software Phase2 is utilized. The circular tunnels are modeled with diameter of 6, 8, 10 and 12 meters in the slopes with dip of 15, 30, 45, 60, and 75 degrees The slopes are supported by end anchored rock bolts with length of 3 meters and spacing of 2 meters. The axial force of rock bolts are measured for releasing stress of 10, 20, 30, 40, 50, 60, 70, 80, 90 and 100 percent in the tunnels. The results of the evaluations show that in the all slopes, with increasing the diameter of the tunnels, the axial force changes of rock bolts has increased. Moreover, with increasing dip of slopes, the impact of releasing stress in the tunnels on the axial force of rock bolts has increased.**

Keywords— Axial force; Releasing stress; Slope; Rock bolt; Tunnel; Phase2

1. INTRODUCTION

Stability of slopes and excavation of rocks is one of the important problems in underground structures engineering. This problem is noticed in both the design and construction stages and a number of methods are used in calculation of slope stability and tunnel excavation of rocks at the moment [1]. After constructing the tunnels, stress condition gets disorganized and its condition around the tunnel gets a new formation which differs from its first condition. Produced stresses due to tunnel excavation are called induced stress [2]. Stress induced instability is one of major concerns for the stability of slopes. The behaviour of slopes largely depends on the releasing stress in the tunnels.

One of the ways to stabilizing of slopes is application of rock bolts. A rock bolt is a long anchor bolt, for stabilizing rock excavations, which may be used in tunnels or rock slopes. It transfers load from the unstable exterior to the confined interior of the rock mass. The rock bolts are almost always installed in a pattern, the design of which depends on the rock quality designation and the type of excavation [3]. Rock bolts work by knitting the rock mass together sufficiently before it can move enough to loosen and fail by unravelling. The rock bolts can become seized throughout their length by small shears in the rock mass, so they are not fully dependent on their pull-out strength.

Rock bolts have been used for years to reinforce the surface and near surface rock of excavated or natural slopes. They are used to improve the stability and load bearing characteristics of a rock mass. When rock bolts are used to reinforce a fractured rock mass, the rock bolts will be subjected to tension, shear and compressive forces. The studies have been done by researchers [4, 5, 6] to reinforce the slopes with rock anchoring. A general rule for rock bolts is that the distance between rock bolts should be approximately equal to three times the average spacing of the planes of weakness in the rock mass, and the bolt length should be twice the bolt spacing [7].

In this research in order to study the effect of releasing stress in tunnels on the axial force of rock bolts in the slopes, the slopes with different dips are modeled and the circular tunnels are excavated in the slopes.

2. THE PHYSICAL AND MECHANICAL CHARACTERISTICS OF THE LIMESTONE

The rock mass properties such as the rock mass strength (σ_{cm}), the rock mass deformation modulus (Em) and the rock mass constants (mb, s and a) were calculated by the RocLab program defined by [8] (Table 1). This program has been developed to provide a convenient means of solving and plotting the equations presented by [8].

In RocLab program, both the rock mass strength and deformation modulus were calculated using equations of [8]. In addition, the rock mass constants were estimated using equations of Geological Strength Index (GSI) [8] together with the value of the shale material constant (mi). Also, the value of disturbance factor (D) that depends on the amount of disturbance in the rock mass associated with the excavation method was considered equal to 0.2 for the limestone in Table 1.

Table 1. Geomechanical parameters of the limestone obtained by using Roclab software

Roclab program's input and output						
Hoek-Brown Classification				Hoek-Brown Criterion		
σ_{ci} (Mpa)	GSI	m_i	D	mb	s	a
Intact Uniaxial Compressiv e Strength	Pick GSI Value	Pick mi Value	Disturbance Factor			
75	44	8	0.2	0.867	0.0013	0.509
Mohr-Coulomb Fit		Rock Mass Parameters				
C (Mpa)	φ(degree)	σ_t (Mpa)	σ_c (Mpa)	σ_{cm} (Mpa)	E_{dm} (Mpa)	
Cohesion	Friction angle	Tensile strength	Uniaxial compressive strength	Global strength	Deformation modulus	
0.529	48.40	-0.110	2.525	9.136	10519.41	

3. NUMMERICAL ANALYSIS

Numerical analyses are done using a two-dimensional hybrid element model, called Phase2 Finite Element Program [9]. This software is used to simulate the three-dimensional excavation of a tunnel. In this finite element simulation, based on the elasto-plastic analysis, deformations and stresses are computed. These analyses used for evaluations of the tunnel stability in the rock masses. The geomechanical properties for these analyses are extracted from Table 1. The generalized Hoek and Brown failure criterion is used to identify elements undergoing yielding and the displacements of the rock masses in the tunnel surrounding.

To study the effect of releasing stress in tunnels on the axial force of rock bolts, the slopes in different dips such as 15, 30, 45, 60, and 75 degrees are modeled. To simulate the excavation of tunnels in the slopes, a finite element models is generated for circular tunnels with diameter of 6, 8, 10 and 12 meters in the middle of slopes. The six-nodded triangular elements are used in the finite element mesh. The end anchored bolts with length of 3 meters and spacing of 2 meters is used for reinforcement of slopes (for example Fig.1).

Fig. 1. The modeling of the circular tunnel with a diameter of 8 meter in the middle section of slope with dip of 15 degrees

The induced stresses in the tunnels are released with the value of 10, 20, 30, 40, 50, 60, 70, 80, 90 and 100 percent, and the effect of it on the axial forces of the rock bolts in the slopes is investigated.

By run of models, the values of rock bolts axial force is measured and the changes it is shown in Figs. 7 to 9.

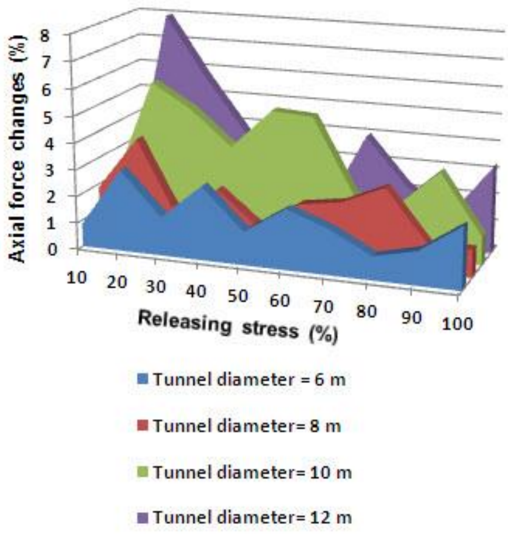

Fig. 2. The axial force changes of rock bolts in terms of releasing stress percentage in the tunnels at the slope with dip of 15 degrees

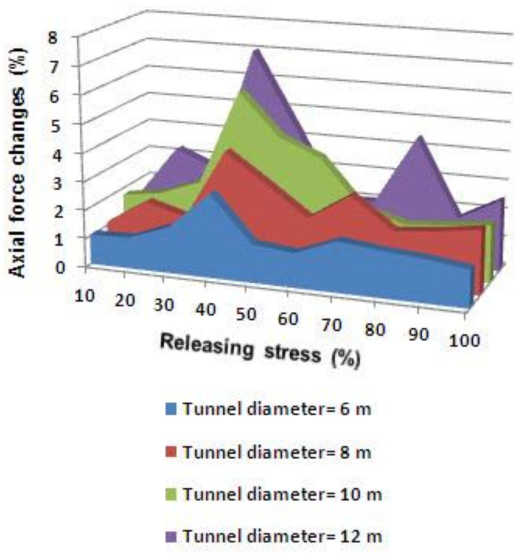

Fig. 3. The axial force changes of rock bolts in terms of releasing stress percentage in the tunnels at the slope with dip of 30 degrees

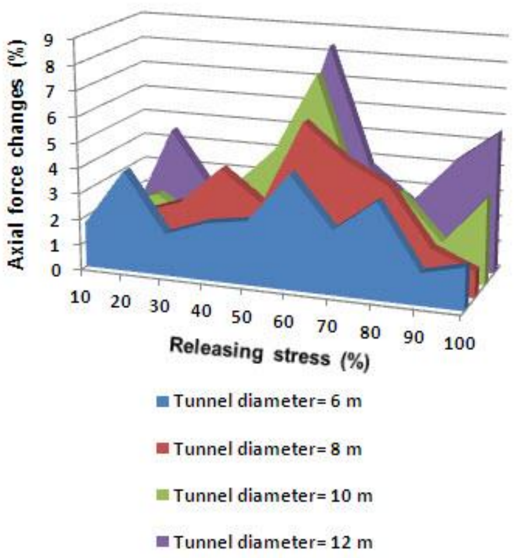

Fig. 4. The axial force changes of rock bolts in terms of releasing stress percentage in the tunnels at the slope with dip of 45 degrees

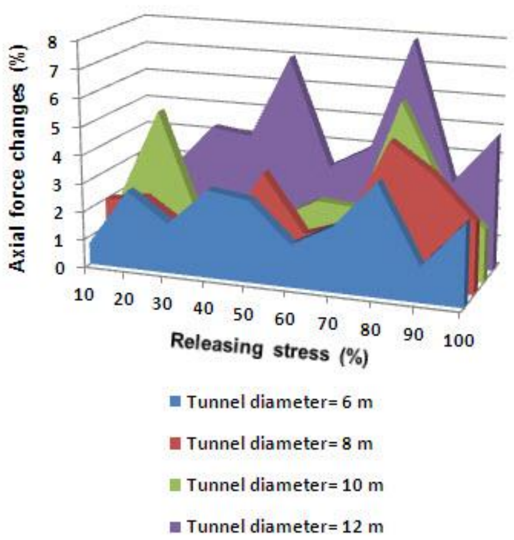

Fig. 5. The axial force changes of rock bolts in terms of releasing stress percentage in the tunnels at the slope with dip of 60 degrees

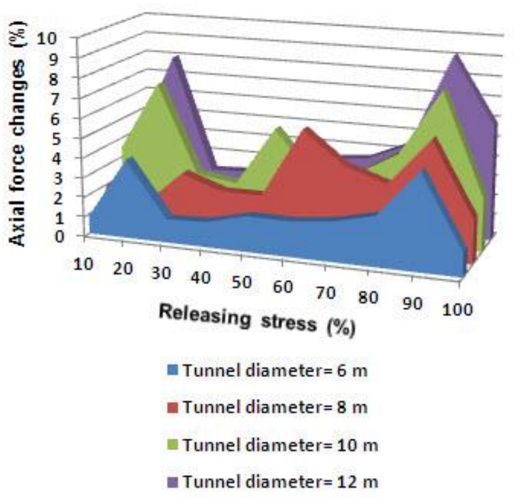

Fig. 6. The axial force changes of rock bolts in terms of releasing stress percentage in the tunnels at the slope with dip of 75 degrees

Based on the above diagrams, it can be seen that in the all slopes with increasing the diameter of the tunnels, the axial force changes of rock bolts has increased. Furthermore, with increasing dip of slopes the axial force changes of rock bolts has somewhat increased. It is important to note that the maximum of axial force changes of rock bolts in the slopes with dip of 15, 30, 45, 60, and 75 degrees has taken place at the releasing stress of 20, 45, 60, 80 and 90 percent, respectively. Therefore, with increasing dip of slopes, the impact of releasing stress in the tunnels on the axial force of rock bolts has increased. This suggests that in the slopes with high dips, we must prevent from high releasing stress in the tunnels. This is possible through quick installation support systems in the tunnels.

4. Conclusions

The results of the evaluations show that by increasing diameter of the tunnels and dip of slopes, the axial force changes of rock bolts has increased. The impact of tunnel diameter in increasing the axial force changes of rock bolts is greater than dip of slopes. Moreover, with increasing dip of slopes, the impact of releasing stress in the tunnels on the axial force of rock bolts has increased.

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